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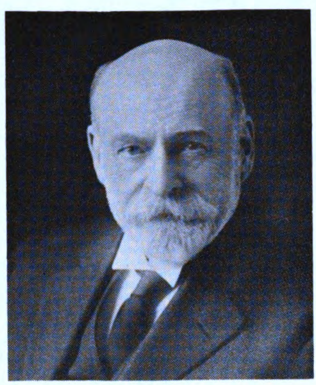

Volume Fifteen Number Four

QUARTERLY

OF THE

COLORADO SCHOOL OF MINES

OCTOBER, 1920

Issued Quarterly by the Colorado School of Mines
Golden, Colorado

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Author's Note

The material in the accompanying pamphlet was collected during a visit to England and Scotland in the summer of 1920. Recent publications on oil shale in these countries are exceedingly scarce. Sir Boverton Redwood devotes only a chapter to the subject. The two classics on the subject are "Mineral Oils", by I. I. Redwood, and the "Oil Shales of the Lothians", both out of print and difficult to obtain.

I am deeply indebted to many gentlemen who were kind enough to aid me in my investigations, but I am under special obligations to the following: Right Hon. Francis G. Kellaway, M.P.; Sir John Cadman, K.C.M.G., H. M. Petroleum Executive; Sir George Beilby, F.R.S., Director Fuel Research Board; Sir Richard Redmayne, Director Mineral Research Bureau; F. E. Powell, Mgr. Dir., Anglo-American Oil Co., Ltd.; Sir Aubrey Strahan, Director H. M. Geological Survey; Wm. Fraser, Mgr. Director, Scottish Oils Ltd.; John Wishart, formerly Mgr. Director, Oakbank Oil Co.; Commander C. D. Burney, R.N., C.M.G.; R. M. Dunwoody, Secretary, Association of British Chambers of Commerce; George P. Toby, Secretary, American Chamber of Commerce; Dr. F. Mallwo Perkin; Dr. J. A. L. Henderson; Dr. Wm. Forbes-Leslie; Dr. Edward Burnet; Dr. Robert Thomas Moore; Prof. W. W. Watts, Royal School of Mines, Prof. S. J. Truscott, Royal School of Mines; A. A. Wolf, Petroleum Technology Department, Royal School of Mines; R. Gilman Brown; J. P. Webster; Albert Lidgett; Harald Nielsen; Dr. W. R. Ormandy; R. S. Dickie; W. Hardy Manfield; E. H. Cunningham-Craig; Arthur W. Eastlake; J. Arthur Greene; Ronald Johnstone; E. Lawson Lomax; F. D. Marshall; E. Baliol Scott, Editor, Mining Journal; Edward Walker, Editor, Mining Magazine.

QUARTERLY

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COLORADO SCHOOL OF MINES

Volume Fifteen | OCTOBER, 1920. | Number Four

The Oil Shale Industry in Scotland and England

By VICTOR C. ALDERSON,
President, Colorado School of Mines.

In Scotland, oil shale is an established industry, operative since 1850, and embraces the mining of the shale, the production of crude shale oil, the refining of the oil into its various commercial products, and the marketing of these products. The profit on each ton of shale mined is approximately two shillings or, under normal exchange, fifty cents. For each ton of shale mined there is one employee; i. e., the total number of employees of all kinds is virtually the same as the number of tons of shale mined each day. The oil shale problem in Scotland embraces the cost of supplies, cost of labor, efficiency of labor, and selling price of the marketable products; in other words, the margin between the cost of production and the selling price. In England the problem is quite different. There are no commercial oil shale plants; as in the United States, there are extensive deposits of oil shale, rich in oil, but, unfortunately, they carry an excess of sulphur—six or eight per cent. or more. This makes the resulting oil virtually worthless for any purpose except for fuel. For this reason, the great problem before the oil shale industry in England is a method of removing this sulphur from the shale during the process of retorting, or from the crude oil without spoiling the oil. Until this technical problem is solved, the oil shale deposits of England are commercially worthless.

SCOTLAND.

SCOTTISH OILS, LTD. The Scottish Oils, Ltd., is a consolidation of the six original Scottish oil shale companies—The Oakbank Oil Co., Ltd.; The Pumpherston Oil Co., Ltd.; The Broxburn Oil Co., Ltd.; Young's Paraffin Light and Mineral Oil Works, Ltd.; James Ross and Co.; Philiptown Oil Works, Ltd.; and the Dalmeny Oil Co., Ltd. The capital stock of Scottish Oils consists of 4,000,000 shares (par value £1, equals $5.00) divided into one million ordinary (common) shares and three million preference (preferred) 7 per cent. non-cumulative shares. The Anglo-Persian Oil, Ltd., controlled by the British Government, has acquired a controlling interest in Scottish Oils, Ltd., and has agreed to furnish, from January 1, 1923, supplies of crude petroleum, in such quantity as may be needed, in addition to the crude shale oil produced, to keep the present refineries of Scottish Oils running at full capacity, at a price based upon a sliding scale. Of the six constituent companies in Scottish Oils, the Broxburn and Young's are engaged in mining, retorting, refining, candle making, and the manufacture

of sulphuric acid; Oakbank and Pumpherston are engaged in mining, retorting, and refining. James Ross and Company and Dalmeny are limited to mining and retorting.

STATISTICS FOR 1915, 1916, 1917, AND 1918.

Employees	1915	1916	1917	1918
Underground	3,856	3,821	4,582	4,153
Above ground......	702	702	742	767
Total	4,558	4,523	5,027	4,920
Total production Long tons	2,992,676	3,009,232	3,116,529	3,000,317
Average price received per ton...	$ 1.39	$ 1.71	$ 2.05	$ 2.47
Total value of annual product	$4,176,000.00	$5,161,470.00	$6,395,000.00	$7,640,390.00

In 1919 the total production of crude shale was 2,758,555 long tons.

In giving the American equivalent for English money five dollars has been assumed to be the equivalent to the English pound sterling. In order to get the exact value, the prevailing rate of exchange should be considered.

	1915	1916	1917	1918
Average yield of crude oil, in gallons	20	20	20	20
Ammonium sulphate, in pounds.	40	44	40	40

DIVIDENDS PAID.

	Per cent. 1914-1915	Per cent. 1915-1916	Per cent. 1916-1917	Per cent. 1917-1918	Per cent. 1918-1919	Per cent. 1919-1920
Pumpherston						
First preference	6	6	6	6	6	6
Second preference ...	6	6	..	..	..	..
Ordinary ...	10	25	40	40	40	30
Oakbank						
Preference ..	6	6	6	6	6	6
Ordinary	..	10	15	15	15	10
Broxburn						
Preference ..	6	6	6	6	6	6
Ordinary	..	7.5	15	15	15	12.5
Youngs						
Ordinary	..	..	5	6	6	2.5

On February 10, 1920, the Scottish Oils, Ltd.—the consolidation of all the Scottish Oil Shale plants—paid a semi-annual dividend of 3.5 per cent. on its preference shares.

PRE-WAR CONDITIONS

Pre-war prices. The following figures are for the year 1911-1912, based upon oil shale that yielded 23 gallons of oil and 45 pounds of ammonium sulphate.

Product	Quantity per ton of shale	Price received	Value per ton of shale
Naphtha	1.90 gal.	$ .10 per gal.	$ .19
Burning oil	5.06 gal.	.08 per gal.	.40
Gas and fuel oil	6.21 gal.	.05 per gal.	.31
Lubricating oil	1.61 gal.	.07 per gal.	.11
Wax	2.28 gal.	.24 per gal.	.54
Total	17.06 gal.		$1.55

Ammonium sulphate, 45 pounds at $0.0278 a pound	$1.25
Price received per ton of shale	$2.80

Total gallons per ton refined	23
Recovery—gallons	17.06
Loss (26 per cent.)	5.95 gallons

Cost of mining	$1.25	to	$1.50
Cost of retorting	.37	to	.43
Cost of refining	.33	to	.50
	$1.95	to	$2.43

Resumé

Price received per ton of shale	$2.80
Cost of production—maximum	2.43
Profit per ton of shale—minimum	$0.37

These figures cover only the actual cost of production; no overhead charges are included.

The distribution of the products in 1911-12 was as follows:

	Per cent.
Naphtha	8
Burning oil	22
Gas and fuel oils	27
Lubricating oil	7
Paraffin wax	10
Refining loss	26
	100

Crude shale oil from Mid Calder now (1920) gives the following products:

	Per cent.
Spirits (gasoline)	7
Kerosene	24
Gas oil	5
Fuel oil	24
Lubricating oil	14
Wax	12
Refining loss	14
	100

MINING At the Westwood pit of the Oakbank Company shale is now being mined from the Middle Dunnet seam at a depth of 640 feet. Upper seams were worked from a shaft now abandoned. One large fault with a throw of 300 feet and many small faults have been found. A vertical shaft was opened four years ago, after

numerous bore holes had been put down, the exact location of the deposit determined, and a complete plan of underground development mapped out. The main shaft is circular, 16 feet in diameter, double compartment, brick walled 14 inches thick. Double cages are used, with room for two cars on each deck. From the bottom of the shaft four main drifts are run, each 12 feet wide, 12 feet high, bricked on both sides and roof. The working faces are 1,680 feet from the shaft. The main drifts are large, well ventilated, and lighted by electricity. The seam of shale now being mined is 12 feet thick, on an average, and dips at an angle of 18°. The roof and floor are good; very little timbering is necessary. Cars of shale are drawn by electricity from near the face of the workings to the main drifts, then by gravity to the shaft, and back to the working faces. This entire plan for moving the shale from the working face to the surface is particularly efficient and economical, and was worked out carefully before the shaft was sunk. The daily production is 640 long tons. The mine is so free from gas that open lamps are used. The mined shale goes in freight cars to the retorting works at Oakbank. The method used in mining at the Westroad pit is the room and pillar and retreating system. The main drifts are driven and pillars 120 feet square are left. During this stage of operation from 15 to 20 per cent. of shale is taken out. The extreme boundaries of the ground to be mined through this shaft are previously determined. When those boundaries are reached the retreating system is followed and the blocks are taken out. Each of the blocks—120 feet square—is divided by cross cuts into four small blocks; these are then taken out in order. The loss in mining is approximately 10 per cent.

GAS, GAS EXPLOSIONS AND ACCIDENTS

No serious gas explosion has ever occurred in any Scottish shale mine. Large gas explosions and fires are virtually unknown. The laws governing the operation of coal mines apply to shale mines, and the same care, method of ventilation, and the safety of workmen that prevail in coal mines are enforced in shale mines. A fireman makes the rounds every morning watching for fire damp. Reports of the condition of the mine are kept and are inspected regularly by government officials. No gas is ever found in the new workings. Marsh gas (CH_4) is sometimes found in small pockets in old workings. Protection is given by hanging up an open lamp. Occasionally a small fire may occur in one of these old workings and a miner may be slightly burned, but the fire is always local and easily extinguished. Such gas explosions and fires as have occurred in this country, where an entire coal mine has been on fire and completely ruined, have never occurred in the shale mines of Scotland during their 70 years of working.

Fatal accidents are also rare. In the past three years only one man has been killed in the Westwood pit. He was killed by a fall of shale at the face.

In the past 12 years at the Mid Breich pit of the Pumpherston company only three deaths have resulted from accidents.

1. A man was killed by the fall of shale at the face.
2. A careless boy was wound round the drum of an engine.
3. A careless boy fell under the wheels of an ore car.

During these 12 years only one man was burned by gas.

HOURS, WAGES, PRODUCTION

At the Westroad Pit mining is done in three shifts of seven hours each; from 7 a. m. to 2 p. m.; from 3 to 10 p. m.; and from 11 p. m. to 6 a. m. All mining is done on the contract or leasing plant. One man is given a block of ground to work; i. e., a lease. He hires his own men, provides all tools, powder and supplies of all kinds, mines the shale, puts it in the cars, and

delivers it to the nearest main haulway. The company then hauls it to the surface. For this the lessee receives from the company four shillings and seven pence or $1.14 a ton. The minimum wages guaranteed to each miner is $3.12, the pre-war rate, plus $1.25, the war bonus, or $4.37. If for any reason, beyond his control, like a thinning of the seam of shale or encountering a fault, his production at $1.14 a ton yields him less than $4.37 a day, the company makes up the difference. If, however, he can increase his production he is at liberty to increase his daily wage as much above the minimum as he pleases. The average amount of shale mined per day per man is 4¾ tons; i. e., one miner and one man for mucking and tramming will, on the average, mine 9½ tons a day; two miners and one trammer will produce 14¼ tons a day. Throughout the shale mines of Scotland the practice is to mine the shale with hand augurs, first with a 1¾-inch, and then with a 1½-inch augur. Black powder is used.

The law does not allow an intoxicated man to work and forbids the sale of liquor about a coal or shale mine. Shale miners regard themselves as being on a higher plane than coal miners. They are a self-respecting class, generally married, live in company houses, "dress up" when not working, and generally maintain a good method of living. The methods, wages, and features of the Westwood pit of the Oakbank company are characteristic of all the shale mines in Scotland.

OIL SHALE SEAMS The oil shale deposits of Scotland consist of 21 strata, in geological order, as follows, beginning with the highest or most recent (Oil Shales of the Lothians, p. 141):

1. Torbanehill or Boghead Mineral. This is at the base of the Coal Measures and overlies the Millstone Grit. It was the first oil shale treated commercially, but became exhausted.
2. This stratum is in the carboniferous limestone: it is 11 inches thick and yielded 29 gallons of oil to the ton.
3. Raeburn or Damhead Shale: three to five feet thick; 30 gallons of oil and 29 pounds of ammonium sulphate.
4. Mungle or Stewart Shale: 17 inches thick; 41 gallons of oil to the ton.
5. Grey Shale of Addiewell: 20 inches thick.
6. Fells Shale: three to five feet thick; the principal shale bed in the West Calder district.
7. Wee Shale of Oakbank; 2 feet thick.
8. Big Shale of Oakbank; 4.5 feet thick.
9. Wild Shale of Oakbank; 6 feet thick.
10. Curley Shale of Broxburn and Oakbank; 6 feet thick.
11. Broxburn; McLean shale of Oakbank; under shale of the West Calder district; 4 to 6 feet thick. This is the principal shale of the Broxburn district.
12. Lower Wild Shale of Oakbank; 4.5 feet thick.
13. Champfleurie Shale. In the Binny sandstone below this stratum is the Binny ozokerite which was used as domestic fuel in Uphall parish a century ago.
14. Dunnet shale; 6 to 12 feet thick; the principal shale of the Pentland, Burntisland, and Duddington fields.
15. Oakbank New Shale or Lower Dunnet seam worked at Oakbank and Pumpherston.
16. Barracks Shale; 8 feet thick, 22 gallons to the ton.
17. Pumpherston No. 1 or Jubilee Shale; 8 feet thick.
18. Pumpherston No. 2 or Maybrick Shale; 5 feet 3 inches thick.
19. Pumpherston No. 3 or Pumpherston Curly Shale; 6.5 feet thick.
20. Pumpherston No. 4 or Plain Shale; 6.5 to 7.5 feet thick.
21. Pumpherston No. 5 or Upper Shale; 4 to 5 feet thick.

The yield of oil and ammonium sulphate varies greatly in the different seams, in the same seam at different localities, and also with the depth of the various seams, e. g., the Torbanehill mineral, the highest in the series, has given the greatest yield of oil, 130 gallons to the ton, but only a few pounds of ammonium sulphate. In the succeeding strata a diminution of oil and an increase of ammonium sulphate is noticed till at the lowest stratum, Pumpherston No. 5, the oil yield is only 20 gallons to the ton, but the ammonium sulphate has risen to 60 pounds to the ton. Also, the Raeburn stratum was best developed in a very small area in the southwestern part of the area; the Fells stratum was developed in the western part where other strata gave less oil; the Broxburn stratum is best at Broxburn; the best part of the Dunnet stratum is in the eastern part of the area.

The following tests of Broxburn shale show the gradual decrease in oil content and gradual increase of ammonium sulphate as depth is reached.

Vertical Depth in Feet	Out-crop	Near Out-crop	438	821	912	...	965	1077	Greatest Depth
Gallons of crude oil...	31.8	29.6	30.7	24.1	25.8	24.8	22.5	17.3	13.5
Ammonium Sulphate, lb.	9.3	10.5	10.4	15.4	11.6	13.4	9.0	16.6	17.1

Thus in a depth of approximately 1,200 feet the oil content has decreased from 31.8 to 13.5 gallons, but the ammonium sulphate produced has risen from 9.3 to 17.1 pounds.

NITROGEN CONTENT. Upon the nitrogen content of the shale depends the yield of ammonium sulphate, although the theoretical yield is not reached in practice. The following table shows the varying nitrogen content and theoretical yield of ammonium sulphate from typical shales:

	Percentage of Nitrogen	Theoretical Yield of Ammonium Sulphate
Broxburn Stratum		
Sample No. 1	0.94	99 lb.
Sample No. 2	0.61	64 lb.
Sample No. 3	0.52	55 lb.
Sample No. 4	0.66	70 lb.
Broxburn Stratum at Mid Calder..	0.70	74 lb.
Broxburn Curly Stratum	0.96	101 lb.
Oakbank		
Big Shale	0.72	76 lb.
Curly Shale	0.575	60 lb.
McLean's Shale	0.646	69 lb.
Dunnet Shale	0.629	66 lb.

SPECIFIC GRAVITY There is a general relation between the specific gravity and the yield of oil, i. e., the lighter the shale the greater the yield of oil, or the heavier the shale the less oil. This is well illustrated by tests on twelve samples from the Dunnet stratum.

	Specific Gravity of the Shale	Yield of Oil in Gallons	Ammonium Sulphate Pounds
1	1.773	30.46	26.72
2	1.841	32.59	24.18
3	2.009	17.22	21.71
4	2.092	17.76	20.11
5	2.100	13.34	19.73
6	2.128	17.24	20.13
7	2.210	7.07	21.30
8	2.238	8.71	20.02
9	2.282	2.45	20.18
10	2.303	8.02	17.84
11	2.443	2.18	13.89
12	2.447	1.94	17.82

Thus in shale of low specific gravity—1.775—the yield of oil is 30.46 gallons; as the specific gravity increases up to 2.447 the oil content decreases to 1.94 gallons.

ANALYSES OF SCOTTISH SHALES

(Oil Shales of the Lothians, p. 154.)

LOCALITY	DESCRIPTION	Hygroscopic Moisture	Volatile Hydrocarbons	Fixed Carbon	Ash	Total	Sulphur Per cent.	Specific Gravity
Torbanehill	Torbanite	0.60	61.42	8.81	29.17	100.00	0.277	1.274
Tarbrax Mine	Raeburn Shale	1.61	30.86	8.82	58.71	100.00	3.053	1.808
Addiewell Mine	Mungle Shale	1.62	32.58	6.93	58.87	100.00	2.276	1.768
Addiewell Mine	Grey Shale	1.03	39.97	3.91	55.09	100.00	0.910	1.942
Cobbinshaw Mine	Fells Curly Shale	0.96	37.16	8.24	53.64	100.00	1.435	1.617
Cobinshaw	Fells Plain Shale	1.45	21.85	5.08	71.62	100.00	1.285	2.174
No. 1 Crossgreen Mine	Broxburn Grey Shale	0.97	31.65	3.36	64.02	100.00	1.219	2.070
No. 1 Crossgreen Mine	Broxburn Curly Shale	1.47	22.85	4.43	71.25	100.00	0.788	1.868
No. 1 Crossgreen Mine	Plain Part of Broxburn Curly Seam	2.22	20.93	4.93	71.92	100.00	0.807	2.028
Hayscraigs Mine	Broxburn Seam	1.72	22.43	5.15	70.70	100.00	0.622	2.047
Deans Mine	Stanley Seam	1.64	23.47	4.72	70.17	100.00	1.896	2.048
Pumpherston No. 5 Mine	Dunnet Shale	1.70	21.35	5.93	71.02	100.00	1.093	1.948
Newliston Mine	Dunnet Shale, Curly	1.57	27.38	8.78	62.27	100.00	1.110	1.804
Newliston Mine	Dunnet Shale, Plain	1.67	26.05	8.08	64.20	100.00	1.246	1.842
Deans Mine	Pattison Shale, Top	1.95	15.80	5.48	76.77	100.00	0.610	2.182
Deans Mine	Pattison Shale, Middle	1.72	24.13	4.98	69.27	100.00	0.668	1.972
Deans Mine	Pattison Shale, Bottom	2.12	15.28	4.83	77.77	100.00	0.528	2.227
Roman Camp Mine	Jubilee Shale	1.92	22.41	1.81	73.86	100.00	0.354	2.177
Roman Camp Mine	Curly Shale	1.47	22.05	1.36	75.12	100.00	1.167	2.210
Roman Camp Mine	Plain Shale	1.45	23.82	4.43	70.30	100.00	1.308	2.079
Roman Camp Mine	Wee Shale	1.40	21.40	1.90	75.30	100.00	0.826	2.224

THE ORIGIN AND NATURE OF KEROGEN

Prof. Crum Brown, F. R. S., was the first to give the name "kerogen" to the "carbonaceous matter in shale that gives rise to crude oil in distillation." The exact nature of kerogen and its origin is a matter of controversy among scientific men. The practical bearing of a solution lies in this: if the exact nature of kerogen can be determined, this knowledge may have a practical bearing on the best method of destructive distillation. If the nature of kerogen can be so determined that it is a foregone conclusion that in the destructive distillation a large amount of unsaturated hydrocarbons (80 to 90 per cent.) will always be formed, then it is a useless task to seek for a retort that will produce only 20 per cent. If, however, the kerogen is shown to be of such a nature that a large production of unsaturated hydrocarbons is due to unscientific methods of distillation, and not to the nature of the kerogen itself, then the successful treatment of shale would not be accomplished until a retort was constructed on such lines as would yield crude oil which contained the minimum amount of unsaturated hydrocarbons.

ORGANIC THEORY

In true oil shale there is no crude oil. A very small amount of oil may be obtained by such solvents as carbon disulphide, but the amount is so small as to be negligible in determining the nature of the oil shale itself. Since carbon and hydrogen compounds produced by inorganic reactions are soluble in carbon disulphide, ether, or similar solvents, it seems very probable that kerogen, the source of the oil in shale, since it does not yield to the usual solvents, must be of organic origin. The organic theory of the origin of kerogen assumes that the contents of a shale stratum were laid down in lake bottoms, lagoons, or estuaries of the ocean, i. e., fairly quiet waters. By the denudation of the land the clay and sand would be deposited along with the remains of vegetable life from the land and animal life from the water. The very large amount of fossil remains found in the oil shale supports this theory.

D. R. Steuart states the case well as follows:

"Some shales are largely made up of entomostraca, and it is probable that the animal matter has in some cases been converted into kerogen. We can imagine kerogen being produced from any kind of organic matter by the action of microbes under special circumstances, the product being dependent on the microbe. Or. on the other hand, kerogen in some cases may be the remains of certain kinds of vegetable matter, like pine pollen or lycopod spores, perhaps little altered, the product being dependent on the nature of the original organic matter. Surmising that kerogen might be some such substance not much altered, we tried to make artificial shale. Dried Florida Fuller's earth was taken, 75 parts, and lycopodium spore dust, 25 parts, to represent the supposed lycopodiaceous **Lepidodendron** spores from our forests by the lagoon, and the mixture was moistened and made into a brick with gentle heat. It was then broken up and distilled in a laboratory retort. Crude oil was obtained equal to 23.8 gallons per ton, sp. gr. .930, and setting point 35° F. (2° C.), and sulphate of ammonia 3.3 lbs. per ton. It was found, however, that lycopodium dust, treated with benzene C_6H_6 Soxhlet fashion, gave up 21 per cent. in solution, which, on evaporation of the benzene, yielded a yellow-brown viscous oil. After thorough extraction of the oil in this way, the remaining insoluble matter of the spore dust was taken and made into a brick as before, and in the proportion of 25 per cent. of the original dust. On retorting, crude oil was obtained equal to 17 gallons per ton, sp. gr. .930, and sulphate of ammonia 1 lb. per ton. The crude oil, specific gravity

and setting point, and the amount of ammonia agreed very well with the figures got from the Torbanehill mineral and the higher shales."

THE INSPISSATION THEORY E. H. Cunningham-Craig takes exception to the organic theory. He is a geologist of world wide experience, has investigated the nature of kerogen by a microscopic study of thin sections, and has correlated oil shale strata with coal seams and petroleum deposits in all parts of the world. His arguments are chiefly geological. His conclusion is that an oil shale stratum should be regarded as the remains of a former oil field; that oil shale fields and oil fields are not two phenomena entirely unrelated but are closely associated in origin and development; that kerogen is "not the mother but the daughter of petroleum". American scientific men and D. R. Steuart, the Scottish authority on oil shales, generally favor the organic theory, but the wide geological observations of Cunningham-Craig and his keen analytical powers demand careful consideration of any theory he may propound. The whole question is one of supreme practical importance, and much additional observation and research are necessary before the nature and origin of kerogen can be regarded as accurately determined.

RETORTING The Scotch retort now in use is a double chambered vertical retort designed not to produce the maximum amount of crude oil, with ammonium sulphate as a secondary consideration, but designed for the purpose of securing the maximum yield of ammonium sulphate, with the yield of oil a secondary consideration. Since most of the American oil shale, thus far tested, gives a high yield of oil and a comparatively small amount of ammonium sulphate, the present Scotch retort cannot be advantageously copied, in toto, with a reasonable expectation of satisfactory commercial success. The older Scotch Henderson retort which was designed primarily for the production of oil, is more likely to meet the conditions of American shale than the present type. This type, with modification, or some form of a horizontal retort, not yet perfected, is most likely to be successful on our American shales.

The present Scotch retort is composed of two chambers, one above the other. The upper chamber is made of cast iron, eleven feet high, two feet in diameter at the top and widened to two feet four inches at the bottom, so that the shale may drop down without clogging. The lower chamber is twenty feet high enlarged at the bottom to three feet in diameter. Shale is fed in at the top from a hopper and descends gradually by gravitation through the retort and is removed as spent shale at the bottom. Heat is applied around the retort from the incondensable gases produced by the retorting. Generally enough gas is produced from the shale itself, but, when lean shale is being retorted, the amount of gas is insufficient. At such times an auxiliary coal fired gas producer is used to supply the necessary amount of gas. The gas enters at the bottom and is forced to circulate around the retort. Into the lower chamber exhaust steam is injected and a temperature of about 1800° Fahr. is maintained. Here the ammonia is formed by the combination of the steam and the nitrogen of the shale. The oil and gas are formed in the upper or cast iron chamber at a temperature of about 900° Fahr. Thus the raw shale enters at the top, is subjected to a heat of 900° Fahr., oil and gas are formed; the shale then drops gradually down through the retort; in the lower chamber it meets the incoming steam, it is subjected to a heat of 1800° Fahr. and ammonia is formed. The entire product, consisting of ammonia, water vapor, oil, and gas sweep upward through the retort and pass out through a large pipe to the condensers. Here the permanent gas is drawn off and goes to the scrubbing tower. The crude oil and water, containing ammonia, flow into separator tanks where, by

the difference of their specific gravities, the oil and water assume different levels and can be drawn off separately for further treatment. These retorts are erected in groups of four; a series of these groups forms a bench; the daily (24 hour) throughput of a retort varies from three to four tons of shale; the time required for the passage of shale varies with the amount of oil produced; the richer the shale, the longer the time required; poorer shale is retorted in less time. No basic changes have heen made, during the past twenty-five years, in the type of retort now in use. Improvements made have been of a mechanical nature in connection with the feed and the discharge, and in the change of the horizontal section of the retort from a circular to an elliptical or rectangular form.

REFINING The products of retorting and condensation are as follows:

(a) Gas.

Permanent gas is drawn to the tower to be scrubbed and then returned to the retorts to be burned in heating the retorts and retorting more shale. In the scrubbing process in the tower, crude naphtha is obtained. This is treated with acid and soda and distilled to get motor spirits and finished naphtha, both ready for the market.

(b) Crude oil and ammoniacal liquor.

These go from the condenser first to the receiving tanks and settled—crude oil at the top (c) and ammoniacal liquor (d) at the bottom.

(c) Crude oil in the receiving tanks.

This goes to the refinery and in the first stage is distilled to get green oil (e).

(d) Ammoniacal liquor.

This is distilled and put through sulphuric acid boxes to get the mother liquor; this is concentrated to get the ammonium sulphate, ready for the market.

(e) Green oil.

This, in the second stage, is distilled and gives

(f) A little naphtha
(g) Crude burning oil
(h) Heavy oil containing paraffin.

(h) Heavy oil containing paraffin.

This is frozen and pressed to get blue oil (i) and crude paraffin (j).

(i) Blue oil.

This is treated with acid and soda and distilled. The distillate is fractionated into gas oil, medium oil, and lubricating oil. The gas oil is ready for the market.

The medium and lubricating oils are treated with acid and soda, settled, and are ready for the market.

(g) Crude burning oil.

This is treated with acid and soda and distilled, and gives as finished products ready for the market

1. Power oil for internal combustion engines (gasoline, petrol)
2. Lamp oil
3. Lighthouse oil.

(j) Crude paraffin.

This is run on the top of water in pans, cooled, and the water runs off leaving the paraffin. The doors of the sweating house are closed and the heat turned on. The gentle heat sweats the excess of oil out of the paraffin. The paraffin wax from the sweating house is washed with

charcoal and put through the filter press. The charcoal is separated from the paraffin. The paraffin is then put into tins for form and size and becomes a finished product for the market. The Henderson sweating system has been used, without material change, for the past 30 years.

The residues from the feed boilers (stills) go to the coking stills and run to dryness. Coke is left. The heavy portions of the distillates, besides coke, are sent to the proper part of the plant. The coke is sold to the aluminum works, is used for fuel in smelting works, or as carbons for lighting purposes. It has less than 1 per cent. of volatile matter.

Tars from the acid washings are neutralized with tars from the soda washings and the neutralized tars are burned in the furnaces.

All residues are sent to their proper places in the plant. The acid and soda treatments take out the unsaturated hydrocarbons and unstable bodies and improve the color. There is a good market for all the products. The refining loss is approximately 25 per cent.

Marketable products according to their specific gravity:

Specific Gravity	Temp. 60° F. (15.5° C.).
0.660 to 0.750	Shale spirit or naphtha; water spirit; gasoline oils too volatile for safety in domestic illumination; used chiefly as solvents and for motor spirit.
0.770 to 0.830	Burning or lamp oils; used for lamps and internal combustion engines.
0.840 to 0.865	Gas or intermediate oils. Properties intermediate between those of the burning and lubricating oils; used for gas making, fuel for the navy, and for internal combustion engines.
0.865 to 0.895	Lubricating oils; high boiling point and viscosity.
Solid paraffin	Melting points from 100° to 130° F. (38° to 54° C.): used for candle making and other purposes.
	Coke.
	Grease.

GENERAL OBSERVATIONS Very little has been published about the Scottish oil shale industry in recent years; little that is new has been developed; standard practice has been adopted and followed: the criterion has been the declaration of dividends: the scientific side has not been studied to any great extent: the early days were the days of rich shale: the Henderson retort was designed to treat these rich shales—30 gallons or more: this retort was discarded, the present double chambered retort adopted, and shale yielding less oil was treated, not because deposits of richer shale were exhausted, but because the leaner shale was easier to retort, gave a crude oil that was easier to refine, produced better commercial products, and contained more nitrogen and, consequently, more ammonium sulphate—thus the leaner grade of shale gave better commercial and financial results; i. e., made more money. Ammonium sulphate now brings £22 ($110.00 normal exchange) a ton at the works for home consumption; for export it brings £56. It is used largely by the sugar beet and cane sugar growers.

The methods used in the Scottish oil shale laboratories to determine the oil and nitrogen content are simple, but check closely with large scale results.

Oil content. Two pounds of broken shale are placed in an iron tube, sealed at one end, seven feet long and two inches in diameter. The sealed end is pushed gradually into an oven. The gas and oil vapors, coming out of the tube, are simply caught, weighed and measured, roughly.

Nitrogen content. An iron tube three feet long and one inch in diameter is filled with raw shale and placed in an oven. Heat is applied

slowly and steam is injected. Vapors are drawn off and sulphuric acid is added to get the ammonium sulphate.

The purpose of the Anglo-Persian Company, in acquiring the oil shale properties in Scotland was, apparently, to secure the extensive and well developed organization; i. e., the refineries, the trade-marks, the distributing machinery, customers, technical men, skilled workmen, and the market.

The Oil Shales of England

THE KIMMERIDGE CLAY

The oil shales of England occur as well-marked strata in the formation known as the Kimmeridge clay. This formation takes its name from the little village of Kimmeridge, in the south of England, two miles from the coast line of the English Channel, near which the formation outcrops and where it was first studied. The formation, about 900 feet thick, has been determined by bore holes and outcrops over a large area of England, viz.: in Dorset, Kent, Sussex, Yorkshire, Lincolnshire, Norfolk, Cambridgeshire, Buckinghamshire, and Wiltshire. The formation is not continuous, but has been eroded in many places before the overlying Upper Cretaceous rocks were deposited. The oil shale strata occur as basins in the upper division of the formation, notably in Dorset, Norfolk, Lincolnshire, and Yorkshire.

THE OIL SHALES OF DORSET

The oil shales at Dorset have been known for many years. The Kimmeridge "Coal Money" was made from oil shale, and was used as currency in very early days, even before the Roman occupation of Britain. Later the shale was used as fuel by the inhabitants of the region. It lies about 300 feet below the top of the Kimmeridge formation. The first commercial effort to ultilize these shales was made in 1848 by the Bituminous Shale Company. The company continued in business for six years, but ultimately failed. Six successive attempts were made up to 1879 to utilize these shales commercially, but each failed, chiefly because of the large sulphur content.

The outcropping of the Kimmeridge shale forms a notable feature of the south of England cliffs on the English Channel for several miles east and west of Kimmeridge Bay in a well marked anticlinal, with some minor faults. The oil shale appears in two well marked strata—the Blackstone and Main Bed. Sir A. Strahan, Director of the Geological Survey, gives analyses of these beds as follows:

Depth of bottom of seam	Stratum	Thickness	Moisture Pct.	Organic Volatile Matter Pct.	Fixed Carbon Pct.	Ash Pct.	Yield of Oil Gallons Per Ton	Specific Gravity of Oil at 15.5° C.	Sulphate of Ammonia Pounds Per Ton	Sulphur in Oil Pct.
89 feet, 11 inches...	Blackstone, Kimmeridge, Bore Hole No. 1.	2 feet, 6 in...	4.2	34.6	19.3	46.1	40.6	0.987	22.7	6.16
77 feet, 4 inches....	Blackstone, Kimmeridge, Bore Hole No. 2.	2 feet, 6.5 in..	2.5	39.1	11.8	46.6	38.4	....	32.4	...
50 feet, 8 inches....	Corton Bore Hole No. 1, Main Bed	2 feet........	6.9	29.5	18.0	52.4	25.5	....	28.5	...
102 feet.......	Corton Bore Hole No. 2, Main Bed	2 feet........	7.5	22.7	11.7	65.6	28.1	1.008	14.6	7.2
24 feet, 9 inches....	Corton Bore Hole No. 3, Main Bed	1 foot, 9 in...	11.0	25.9	11.3	51.8	29.9	....	25.3	...
10 feet, 5 inches....	Corton Bore Hole No. 1, Main Bed	2 feet, 1 in...	6.5	33.5	11.8	48.8	29.1	....	26.1	...

COMPLETE ANALYSES.

	Kimmeridge Blackstone Bore Hole No. 1	Corton Main Bed Bore Hole No. 2
Carbon	37.94	26.75
Hydrogen	4.19	3.67
Nitrogen	1.03	0.57
Sulphur	4.51	5.57
Oxygen (by difference)	3.88	2.79
Ash	48.45	60.65
	100.00	100.00

The specific gravity of the shale from the Kimmeridge was 1.775; from the Corton 1.645: at 15.5° C.

The old shaft, tunnel, and bore holes near Kimmeridge have long been abandoned. The present workings are at Corton, near Weymouth, in an outcrop of the Blackstone seam. Six adits 1,000 feet apart are being driven. Four are each 350 feet long and two 60 feet long. Here the Blackstone seam consists of two strata—3 feet and two feet 6 inches thick, with a clay stratum 2 feet thick between.

The estimated resources from these Blackstone and Corton strata are as follows:

Blackstone: thickness 2 feet 6 inches: tons per acre, 4,375; total tons of shale, 12 million; average yield, 37.6 imperial gallons of dry oil; ammonium sulphate (28.6 pounds per ton) 161,820 pounds; total gallons of oil, 363,000,000.

Corton. Main Bed: thickness, 2 feet; tons per acre, 3,500; total tons of shale, 5,000,000; average yield, 28 0 imperial gallons of dry oil; ammonium sulphate (26.3 pounds per ton) 61,500; total gallons of oil, 147,000,000.

A sample of the Blackstone seam tested at the Colorado School of Mines gave: Oil, 51.59 gallons of oil per ton, and 5.79 per cent. of sulphur.

OIL SHALES IN LINCOLNSHIRE AND YORKSHIRE The presence of the Kimmeridge clay is known to exist in both Lincolnshire and Yorkshire, particularly from bore holes. Bituminous shales have been found, but they are not of commercial importance.

THE OIL SHALES OF NORFOLK The Kimmeridge clay formation in Norfolk County has been well explored by open cuts, bore holes, and shafts, in the region south of King's Lynn and east of Ouse. The oil shale appears in two series; the upper called the Smith's series and the lower the Puny Drain series, virtually at the top of the Kimmeridge clay. An open cut or quarry on the property of the English Oilfields, Ltd., shows a seven foot stratum of oil shale, wet and oily, beneath an overburden of from 13 to 30 feet in thickness. The dip is 5 degrees to the east. The deposit has been tested by pits and bore holes over an area of two square miles. A 50-foot shaft, 6 by 12 feet, has been sunk to an eight foot stratum of oil shale. This stratum consists of two distinct layers: the upper, or black shale, 3 feet 6 inches thick; and a lower stratum, 4 feet 6 inches thick. The roof is soft so that the walls and roof of the main drifts need to be bricked. A sample of the shale tested at the Colorado School of Mines gave: Oil, 17 gallons per ton; sulphur, 5.48 per cent.

ANALYSIS OF NORFOLK SHALE.
(British Mineral Oils, p. 172)

	Smith Series Per cent.	Puny Drain Series Per cent.
Moisture	9.8	8.0
Volatile organic matter	35.1	31.7
Fixed carbon	15.3	16.3
Ash	39.8	44
	100.0	100.0

ANALYSIS OF THE ASH.

Silica	49.50
Alumina	20.20
Ferric oxide	10.27
Lime	11.68
Magnesia	1.22
Sulphuric acid	6.30
Phosphoric acid	.83

ENGLISH OILFIELDS, LTD. The English Oilfields, Ltd., is the largest oil shale company in the Norfolk district. It owns, or controls by long lease, sixty square miles of territory. It is capitalized at £1,500,000 ($7,500,000) in shares of one pound sterling each. The company is making extensive improvements on their property consisting of a branch from the main line of the Great Eastern Railway; houses for workmen; retorts, condensers, scrubbers, refinery shops, and by-product plant, with the intention of establishing a plant complete in all details. Besides it has erected and tested several retorts for the distillation of its shale.

THE REMOVAL OF SULPHUR FROM OIL SHALE Fortunately for the oil shale industry in the United States, sulphur in the oil shale here has not yet been found in quantity to be detrimental to the oil produced. Also, there is little or no sulphur in the Scottish shale. But in England the known beds of oil shale all carry so much sulphur as to make the oil unmarketable except for fuel. During the war, the British Admiralty raised the allowable limit of sulphur in oil to three per cent., but paid a low price for any above two per cent. The one great obstacle standing in the way of the development of the oil shale industry in England is the desulphurization of the shale without spoiling the oil. Logically there are three methods of attack.

A. During the retorting of the shale an attempt may be made to remove the sulphur by such agents as lime and caustic soda.

B. As soon as the oil vapors and gas are evolved, and before condensation, they may be passed over desulphurizing agents.

C. After the vapors have been condensed the oil may be desulphurized by some chemical means.

Many patents have been taken out to cover processes and many individuals claim to have a solution, yet no process has yet appeared that satisfies commercial and industrial requirements. During the Great War the need of a domestic supply of oil was felt so keenly by the British Government that it investigated every possible source of supply. In the case of oil shale the presence of an excess of sulphur stood as an insurmountable obstacle. It remains the great unsolved problem before the technical men of Great Britain. When its solution comes, as it probably will some day, great quantities of oil shale in the Kimmeridge formation,

now commercially valueless, will become a source of great wealth to the British Empire, and of economic importance in supplying an additional domestic supply of oil.

Besides the technical point of view, it is to be observed that, in an utilitarian age like the present, the aesthetic objection to the odor of sulphur bearing oil may have to be ignored because of grim industrial necessity. Also sulphur bearing oils may have to be mixed with non-sulphur bearing oils to reduce the average percentage of sulphur below the objectionable point. However, the only solution that will be permanently satisfactory will be the production of sulphur free from oil.

Sulphur occurs in shale oil and petroleum both in the form of organic and inorganic compounds, and even as free sulphur dissolved in the oil. The sulphur in inorganic compounds may usually be removed without much difficulty, either in the process of distillation, or by treatment of the distillate. Some organic compounds of sulphur are more or less decomposed by distillation, so that a partial removal of the sulphur is easily effected, but the complete elimination of organic sulphur from an oil may prove very difficult commercially. The exact conditions or combinations in which the sulphur exists, which are not definitely known, and which may vary in different oils, add to the difficulties of the case. Many methods have been proposed for the elimination of sulphur and some have proved successful with certain oils. Unsaturated organic compounds containing sulphur can be removed with sulphuric acid, but ordinary sulphur free, unsaturated compounds are more easily attacked, and, therefore, if the oil contains a large percentage of the latter, the process becomes too expensive. Also, it is possible for sulphur to be actually added in the process by the formation of sulphonic acids. Liquid sulphurous acid has been used in the Edeleanu process to remove sulphur. It combines with the unsaturated sulphur compounds and settles out of the oil. But not all the sulphur is necessarily in combination with unsaturated compounds. Metallic oxides, such as cupric oxide, have been employed to combine with and eliminate sulphur. This is done, either by bringing the hot vapors of distillation in contact with the oxide, or agitation of the latter with the hot oil. By the Frash process the amount of sulphur can be reduced to 5 per cent. without spoiling the oil, but not below that point. These and other methods are employed with more or less success according to the nature of the oil, but the problem as a whole is apparently still unsolved. Among the forms in which sulphur has been found in shale oil or petroleum may be mentioned:

- Free sulphur;
- Hydrogen sulphide;
- Thiophanes;
- Alkyl sulphides;
- Mercaptans (in Baku oil);
- Carbon disulphide; and
- Alkyl compounds of carbon disulphide.

In any case, the problem is a serious one and vital to the development of the oil shale industry in England.

RESULTS OF DESULPHURIZING EXPERIMENTS WITH SHALE OIL FROM NORFOLK CO., ENGLAND.

(Treatise on British Mineral Oils, page 173.)

	Per cent. of sulphur in the oil
Untreated dry oil	8.9
Shale distilled with caustic soda and lime	6.0
Shale oil passed over red hot iron	7.4
Shale oil treated with sodium plumbite	7.2
Shale oil treated with mercuric sulphate	7.4

Shale oil treated with alcoholic mercuric chloride..	6.0
Shale oil 20 per cent. of 80 per cent. sulphuric acid and distilled up to 200° C....................	4.45
Shale oil treated with aluminum chloride..........	3.7
Shale oil treated with large excess sulphuric acid..	0.55
Shale oil treated with fuming sulphuric acid—the oil entirely dissolved.	

INVESTIGATIONS BY THE BRITISH GOVERNMENT On account of the shortage of petroleum and its products during the Great War, especially fuel oil for the Admiralty, the British Government directed its attention to the possible production of petroleum from home supplies; i. e., from Scotland and England alone. First of all, efforts were made to increase production from the known deposits of oil shale in Scotland by speeding up the mining of raw shale, by using to full capacity the retorts in use, and by putting in use older retorts that had been lying idle. By these efforts the output was increased, but not to a degree sufficient to meet the pressing needs. Investigations were then carried on with the deposits of oil shale which were known to exist in Dorsetshire, Norfolk and elsewhere, but on investigation these shales were found to produce an oil too high in sulphur for Admiralty purposes and various retorts and processes were tried in order to produce a suitable oil from these shales and an oil which was free from sulphur. In 1917 the Inter-departmental Committee carried out experiments with the Del Monte retort, a low temperature distillation process, on the Kimmeridge shales which gave an output of 45 gallons a ton, but carried 6.6 per cent. of sulphur. An endeavor was then made to find a process for eliminating this sulphur, and from June to October, 1917, experiments were carried on and investigations made of the process invented by Heyl which failed to produce the results obtained by the inventor. Other processes examined were Burnet's process for desulphurizing the oil obtained from the Norfolk shales. Still other processes investigated were Tozer's system for producing oil by low temperature vacuum process distillation, the S. O. S. system for the retorting of sewage sludge, the Simpson system, the Moeller system, the Maclaurin system, and the Lamplough process. Oil shales from other parts of the country were also investigated, namely, at Anglesey, and at Skipton in Yorkshire. Having failed to find any satisfactory process for eliminating this sulphur, attention was directed to the cannel coal and torbanite which were known to exist in various parts of the country, and which were capable of producing a high percentage of oil.

GENERAL OBSERVATIONS The English oil shale deposits are essentially different from those investigated elsewhere and present specialized problems of desulphurization, retorting, and refining. They are particularly characterized by:

a. A high specific gravity.
b. A large content of olefines and unsaturated hydrocarbons.
c. A low content of the paraffin and naphthenic series.
d. A high percentage of sulphur.

To those who foresee a high price for the ammonium sulphate produced from shale a note of warning should be sounded. The high price of ammonium sulphate, obtainable in Scotland, is the result of peculiar local and industrial conditions and should not be regarded as a criterion for the United States. Here the synthetic production of ammonium sulphate has progressed to such a point that its market price in the future will be lower than it has been in the past, so that a high price for ammonium sulphate, as a product from crude shale oil, should not be counted upon.

Good oil shales have low specific gravities. The specific gravity of ordinary clay shale varies from 2.4 to 2.5. The specific gravity of oil shale is seldom more than 2.4 and may go as low as 1.4. As a general rule the lower the specific gravity the richer the oil content.

DETERMINATIONS OF SPECIFIC GRAVITY AT THE COLORADO SCHOOL OF MINES.

Locality	Specific Gravity at 15.5 C.
Grand Valley, Colo.	1.59
Grand Valley, Colo.	1.768
Norfolk Co., England	1.748
Norfolk Co., England	1.720
Oakbank, Scotland	1.977
Corton, England	1.409
Mussel Bank, Scotland	1.635
College Bridge, New Brunswick, Canada	1.650
Pumpherston, Scotland	2.317
Albert Mines, New Brunswick, Canada	1.675
Gaspie County, Quebec, Canada	2.178

THE USE OF STEAM.

Advantages.

1. Increase in the value of the oil (a practical observation in Scotland.
2. Dilution of the oil and gas vapors.
3. Increase in the velocity of the discharge.
4. Oil and gas vapors are swept away from the hot zone and secondary decomposition reduced.
5. Increase in the paraffin products (a practical observation in Scotland).
6. Equalization of the temperature.

In the opinion of the Scotch operators exhaust steam should always be used. This is based upon years of practical experience rather than upon theoretical consideration, but it may be noted that ammonium sulphate, rather than oil, is the primary consideration.

Disadvantages.

1. One hundred gallons of water, in the form of steam, are needed for each ton of shale retorted. This may be difficult to obtain in a semiarid region.

2. Increased first cost of installation and subsequent cost of condensation.

Directory of Scottish and English Oil Shale Retorts

Scotch Practice:

Wm. Fraser, Manager-Director Scottish Oils, Ltd.,
135 Buchanan Street,
Glasgow, Scotland.

Vertical, circular type; two sections; upper section of cast iron; upper diameter, two feet; lower diameter, 2 feet 4 inches; height, 11 feet; lower section enlarged to three feet in diameter; 20 feet high; entire retort encased in brick; four retorts in a house; 16 houses form a bench; throughput 3 to 4 tons in 24 hours; temperature in the upper section, 900

to 1000° Fahr., in the lower section 1800 to 2000° Fahr.; shale broken only to about the size of one's two fists; feed and discharge continues; externally gas heated; gas from the shale generally sufficient but an auxiliary gas producer is kept in readiness for use when lean shale is retorted and supply of gas from the shale is insufficient; exhaust steam is injected at the bottom; gas and oil vapors are drawn off at the top; less steam is needed if shale is in large pieces, more if shale is small; rich shale takes more time for retorting; lean shale less time; gas and oil vapors are produced in the upper chamber, ammonia in the lower chamber.

This type of retort is used in all the Scottish plants and has been in successful commercial operation for twenty years. It is designed especially for the maximum production of ammonium sulphate. Minor changes have been made, but these changes are only in the mechanical details of the feed and discharge; and in the shape of the cross section; e. g., in the Pumpherston retort the spent shale drops out at the bottom, but in the new Thompson retort the shale comes out through a door at the side. The Broxburn retort has an oval and the Thompson an oblong cross section.

N. M. G. Process:

F. D. Marshall, 19 Queen Anne's Chambers,
Tothill St., Westminster,
London, S. W. 1,
England.

Harald Nielsen,
13 Firs Ave.,
Muswell Hill, London N. 10.

This process is being tested under commercial conditions. Details are not yet available.

Perkin Retort:

Dr. F. Mallwo Perkin, 59 Albion House,
New Oxford St.,
London, S. W. 2,
England.

Stationary horizontal type: rectangular cross section: length, 55 feet; width, 5 feet; height, 8 inches. Shale is advanced by teeth protruding from the base: teeth are four inches apart, staggered and have a forward, downward, backward, and upward motion: gas fired from underneath; gas and oil vapors removed through series of vents from top of retort under slight suction: feed and discharge continuous.

Universal Retort:

G. F. Bale,
4 Featherstone Bldg.,
London, W. C.,
England.

Vertical, circular type: internally gas fired; height, 20 feet; diameter at top, 18 inches; at bottom, 2 feet 2 inches; feed and discharge continuous; discharge by a ram—forward and backward motion; steam, gas, and air admitted at bottom; shale broken to 2 inch mesh; gas and oil vapors drawn off together at the top.

Wise Continuous Retort:

Wilfrid Wise,
36 Victoria St.,
London, S. W. 1,
England.

Stationary horizontal type: length, 180 feet; width, 7 feet; shale broken to half inch mesh; shale advanced through retort by means of

baffles; throughput, 100 tons in 24 hours; gas fired underneath; gas and oil vapors withdrawn from series of vents under suction; continuous feed and discharge.

Maclaurin Retort:

Robert Maclaurin,
Grangemouth, Scotland.

Vertical type; diameter, 4 feet at the top, 10 feet at the bottom; 30 to 40 tons are put in at a charge and stay in the retort 48 hours; temperature, 550° C.; superheated steam injected at the bottom; gas producer gas made from the spent shale.

Burnet Tubular Retort:

Dr. Edward Burnet,
93 Harley St.,
London, S. W. 1,
England.

Vertical type, 26 feet high; cross section oval; long diameter at top, 6 feet; at bottom, 7 feet; short diameter at the top, 3 inches; at the bottom, 5.5 inches; shale broken to half inch mesh; seven annular rings, upper three of cast iron and lower four of refractory material; heat from gas applied externally; temperature regulated; feed and discharge continuous; gas and oil vapors taken off at intersections or rings; steam injected at bottom and half way up; temperature 400° C.; throughput 20 tons in 24 hours; six retorts designed for one bench.

Kimwall Retort:

A. L. Sidney,
Care of Joseph Kimber & Co.,
23 Philpot Lane,
London, E. C.,
England.

Vertical type, 15 feet high; bulging at the sides; smallest inside diameter, 3.5 feet; largest, 4 feet; construction, in three parts; inner section, fire brick, 6 inches thick; middle section fire clay, 4 inches thick; outer section, ordinary brick, 14 inches thick; no iron used; shale broken to 2 inch mesh; capacity of retort, 2.5 tons; throughput, 12 tons in 24 hours; gas and oil vapors withdrawn at the top; no external heat is applied; superheated steam by the Bynoe system, at a temperature of 500° Fahr. is injected at the bottom and comes in direct contact with the shale.

This retort is erected and is being operated for testing shale, at the coal mine of the Ayrshire Coal and Oil Company, near Stewarton, 23 miles from Glasgow, Scotland.

Burney Retort:

Commander C. N. Burney, R.M., C.M.G.,
20 Wilton Crescent,
London, S. W. 1,
England.

Stationary, horizontal, cylindrical type; thirty feet long; 6 feet in diameter; shale advanced by means of a revolving helical screw; shale broken to 1.5 inch mesh, or less; shale passes between the periphery of the cylinder and the exterior of the threads of the screw; heating gas passes within the ribs of the screw and, by induction, distills the shale; heat controlled by speed at which gas is drawn through; gas and oil vapors drawn off by suction from six vents; continuous feed and discharge; temperature 550 to 600° F.; 24 hour throughput, 75 tons.

Cheswick Retort:

John Gallon, Supt.,
Carbon Products and Distillation Co.,
Church Wharf,
Cheswick, London.

Horizontal, cylindrical, stationary type; 25 feet long; 18 inches in diameter; shale advanced by revolution of internal helical screw; shale broken to 1.5 inch mesh; gas and oil vapors drawn from series of vents; gas fired beneath retort; temperature 450 to 480° C.; continuous feed and discharge; throughput, two tons in 24 hours.

The British Government used this retort during the Great War. For nearly a year it was in almost constant use, and hundreds of tests were made with it, yet the retort itself has never been given a thorough test to determine its own efficiency as a commercially successful retort. Its use by the Government was a war measure, merely to determine the oil content of the many varieties of oil shale submitted to it.

Trozer Retort:

C. W. Trozer,
66 Victoria St.,
Westminster,
London, S. W. 1,
England.

Vertical type; height, 10 feet; diameter, 40 inches at the top; slightly larger at the bottom; feed and discharge intermittent; one charge is fully treated and the residue removed before a new charge is put in; time of treatment, 4.5 hours; throughput, 5 tons in 24 hours; gas and oil vapors are removed through a central vertical duct. The peculiarity of this retort is the internal construction, especially the cross section. In order to secure a large heating surface for the shale to come in contact with, and at the same time have a thin layer of shale, the interior of the retort has a series of circular iron sections joined by radial iron partitions. The retort is externally fired and the heat is conducted through the iron to the shale.

This retort is erected at Battersea, London, and has been used extensively, especially in experimental work on the low temperature carbonization of coal as well as the retorting of shale.

English Oilfields Retort:

Dr. William Forbes-Leslie,
8 Buckingham Palace Mansions,
London, S. W. 1,
England.

Vertical type; two chambered; upper tapering section, 11 feet high; lower vertical section, 17 feet high; total height, 28 feet; oval cross section; long diameter, at the top, 2 feet 6 inches; short diameter, 13 inches; slightly larger at the bottom; steam injected at the bottom; externally heated; three separate vents for the withdrawal of gas and oil vapors from the upper tapering section; throughput, 4 tons in 24 hours.

This retort may be regarded as a modification of the present Scotch type; it is under construction by the English Oilfields, Ltd., on its property in Norfolk County five miles south of King's Lynn, England.

Fraser Retort:

William Fraser,
Castle Hotel,
Downham Market,
Norfolk County, England.

Combined vertical and inclined type; three sections; lower vertical,

12 feet high; middle inclined at an angle of 45°, 10 feet long; upper, vertical, 8 feet high; construction entirely of fire brick and clay; gas and oil vapors taken off in two places from the upper section; continuous feed and discharge; steam injected at the bottom; oval cross section; long diameter four feet; short diameter, 9 inches.

The purpose in putting an oblique section between two vertical sections is to change the position of the whole body of shale in its descent, break up the column, and thus facilitate the upward passage of the vapors.

It may be regarded as a modified Scotch type. It is erected on the property of the English Oilfields, Ltd., five miles south of King's Lynn, Norfolk County, England.

Simpson Retort:

Simpson Process, Ltd.,
Billiter St.,
London, England.

Vertical type; 21 feet high; oval cross section; continuous feed and discharge; iron construction with brick casing; externally fired; exhaust steam injected at the base; gas and oil vapors drawn off at the bottom under a 2-inch vacuum.

This retort is erected on the property of the English Oilfields, Ltd., five miles south of King's Lynn, Norfolk County, England.

Freeman Multiple Retort:

Nat. H. Freeman,
9 Southampton St., W. C. 2,
Care Educational Pub. Co.,
London,
England.

This retort is of the vertical type and consists of a number of successive chambers one above the other through which the shale passes and is subjected to a successive increased range of carefully controlled heat. The shale is ground to pass a 10-mesh and fed into the first and upper compartment where the temperature is maintained at the boiling point of water to expel the moisture. The shale then passes to the second and next lower chamber where the temperature is regulated according to the product required; e. g., for gasoline, 150°; the material then passes to the third chamber where naphtha is produced at a temperature of 200 to 205° C. The next chamber produces kerosene and the next fuel oil. The maximum temperature reached is 600° Centigrade. The distinguishing feature of this process is the control of the heat by means of the Freeman Precision Temperature Control.

Fell Retort:

John Fell, Managing Director,
Commonwealth Oil Co.,
117-119 George St.,
Sydney, New South Wales.

CONCLUSIONS After a two months study of the oil shale industry in England and Scotland, I am led to the following conclusions:

a. The present Scotch methods are well adapted to the shale treated; they are commercially successful and meet the local conditions.

b. The Scotch plants are the result of seventy years of operation; they have been improved from time to time, but naturally are not now so arranged as to be highly efficient from an operative point of view, yet it would be folly to scrap them and rebuild in more modern plans.

c. Scotch methods should not be slavishly followed in other countries unless conditions are identical.

d. The problem in Scotland is one of operating efficiency—the difference between cost of production and selling price.

e. The problem in England is not yet a commercial one—but technical.

f. The presence of an excess of sulphur in all oil shale deposits of England demands that some effective and economical method for the elimination of the sulphur be devised.

g. Where sulphur does not occur to an objectionable amount, as in the United States, the serious problem is the design of an efficient retort.

h. Many retorts are in process of development. At the present writing, it is virtually impossible for any one (except the inventor himself) to select the best.

i. In my judgment, the successful retort will be one of three types.

1. The present Scotch type, where local conditions are identical with those in Scotland.
2. A vertical, modified Scotch type, adapted to shale rich in oil, but low in nitrogen content, or,
3. A horizontal type, which will be based on correct scientific principles and be absolutely new.

It is not impossible that successful retorts of all three types will result. The keynote to the successful production of oil from shale is a retort adapted to the character of the shale to be treated.

DATE DUE
